Neutrino oscillations at accelerators

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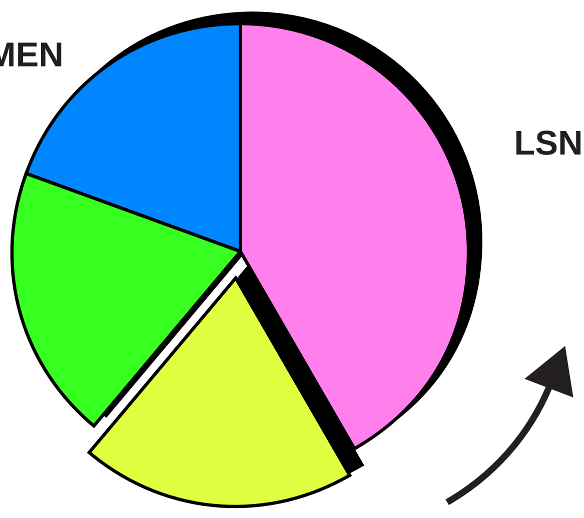
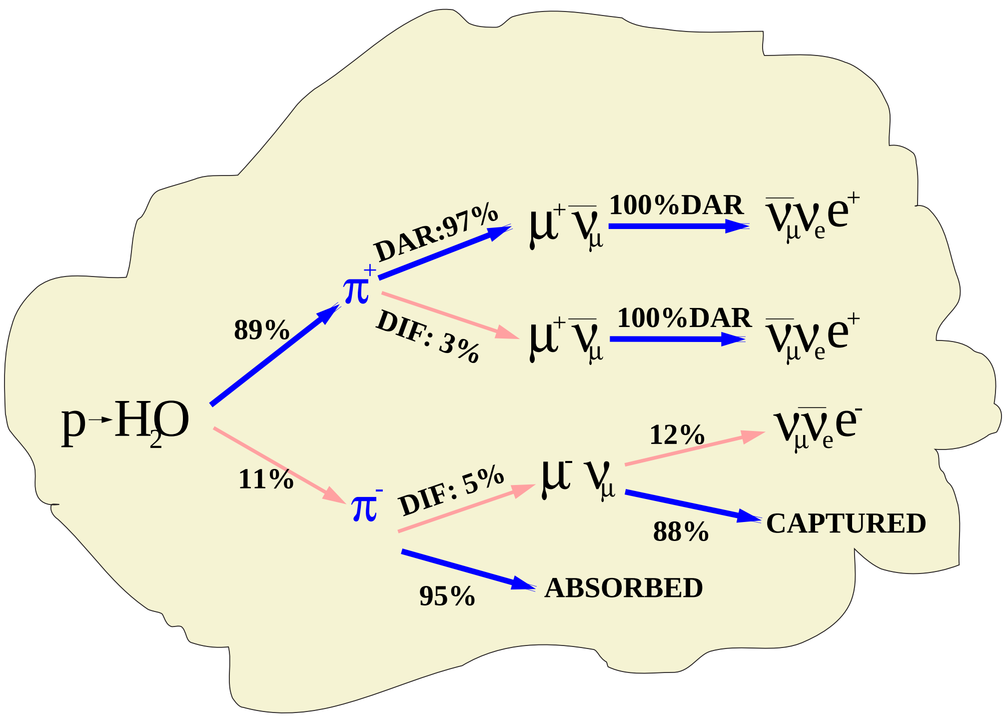


LSND experiment at the Los Alamos Meson Physics Facility (LAMPF)

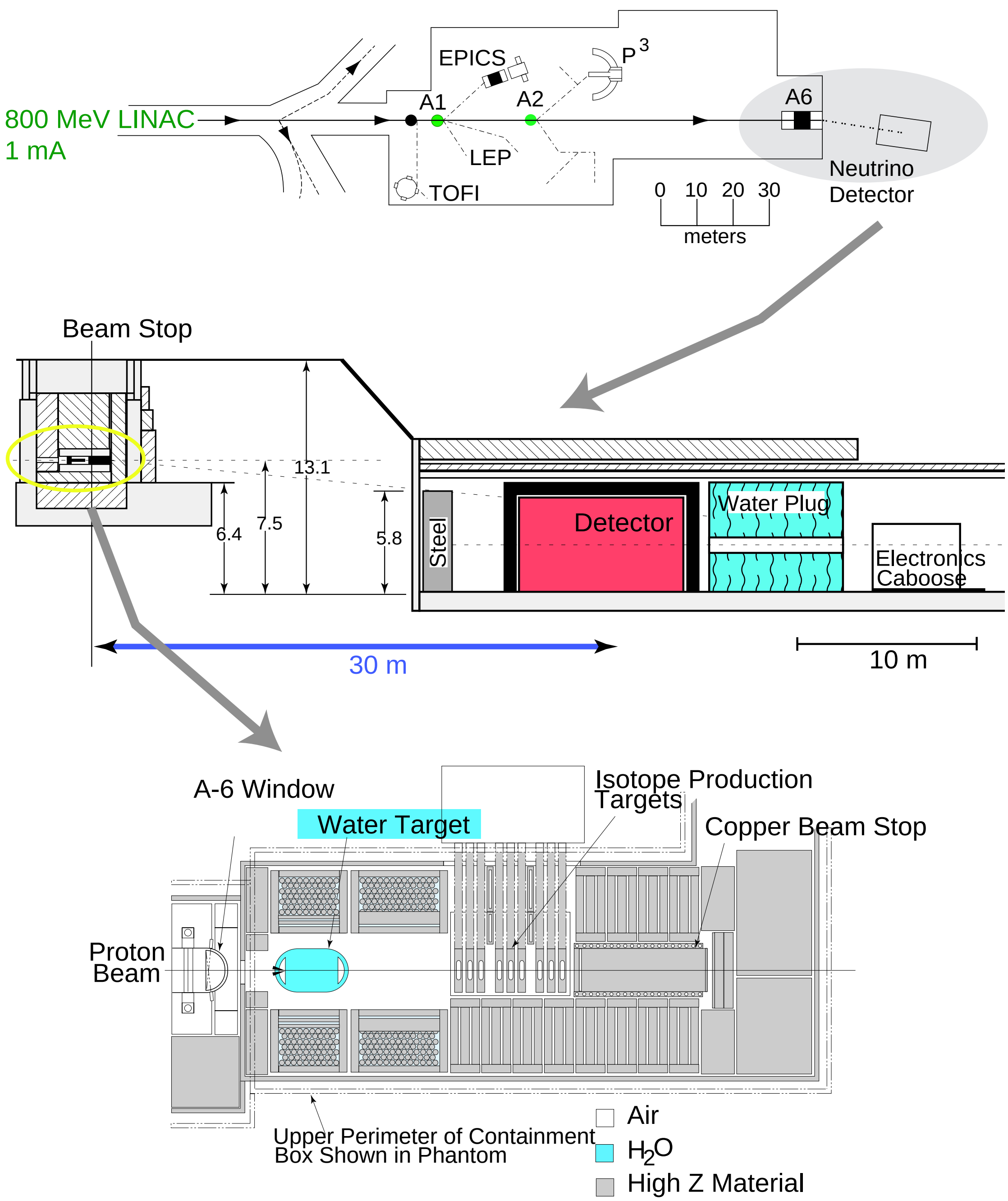
Neutrino Source High intensity (1mA) low energy (800 MeV) p beam into stop target

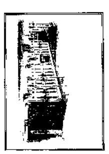
Look for $\overline{\nu}_\mu \to \overline{\nu}_e$ oscillation from decay at rest (DAR) neutrino flux and for $\nu_\mu \to \nu_e$ oscillation from decay in flight (DIF) neutrino flux.



- $\overline{\nu}_e$ flux is $\overline{\nu}_e / \overline{\nu}_\mu$ (DAR) = $7.8 \cdot 10^{-4}$
- Oscillated $\overline{\nu}_e$ events have a maximum energy of 52.8 MeV.
- No electron from ν_e above 36 MeV ($\nu_e^{12}C \to e^{-\ 12}N$)
- No electron with a correlated γ above 20 MeV ($\nu_e^{12}C \to e^- n^{11}N$)

LSND Experimental Layout





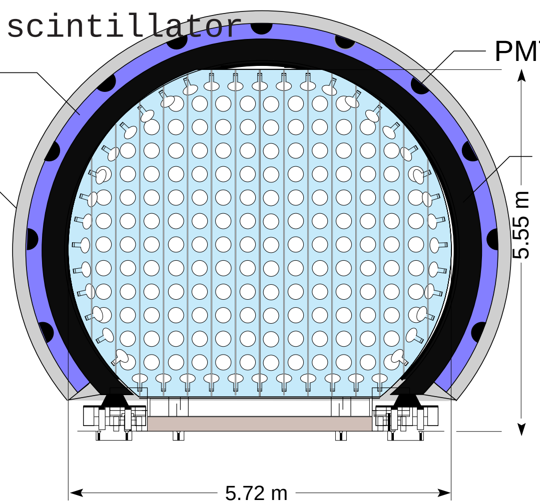
Liquid Scintillator Neutrino Detector

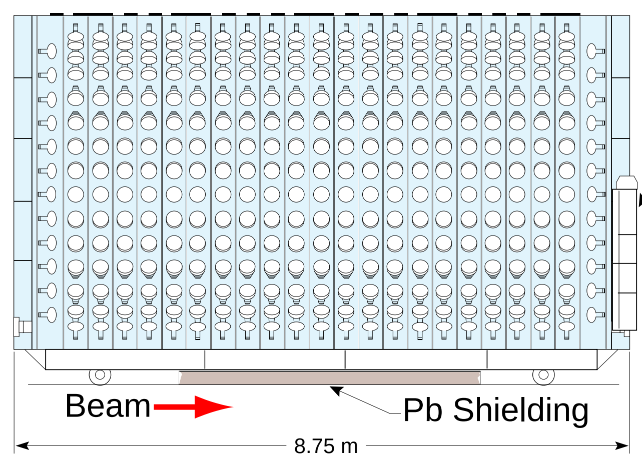
167t of Dilute Mineral Oil

Cerenkov light (n=1.47): threshold+direction
Scintillation: energy
Cerenkov/scintillation: particle identification

central detector: 1220x8" PMT (25% surface coverage) mineral oil (CH2) doped with 0.031 g/l of b-PBD .

veto detector: 292x8" PMT, passive shield: ~2 Kg/cm2

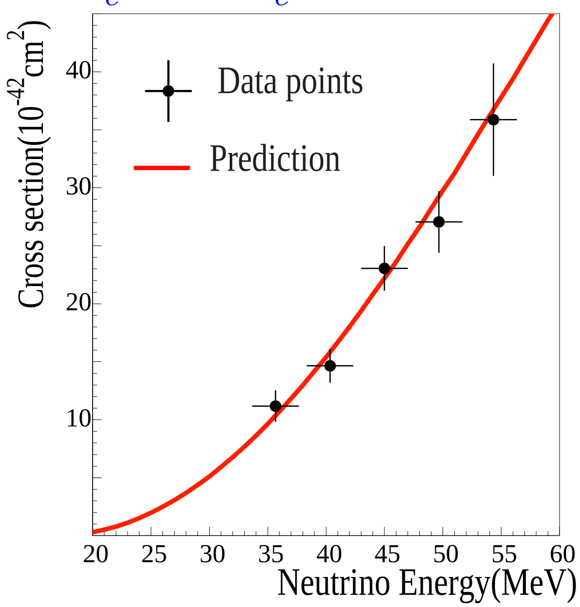




DATA TAKING

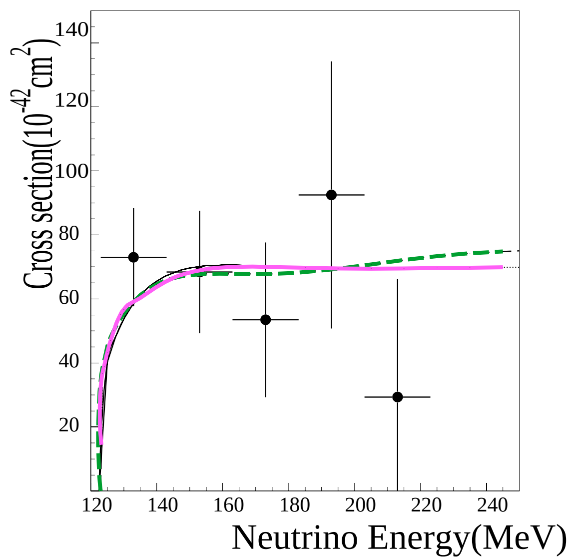
YEAR	COULOMBS	
1993	1787	
1994	5904	First DAR paper: "Candidate events .." (PRL 75(1995)2650)
1995	7081	Second DAR paper: "Evidence for ...", (Ph.Rev.C 54(1996)2685 and PRL 77(1996)3082 "
		DIF paper: " Results on ...", (PRL 81(1998)1774 and Ph.Rev.C 58(1998)2489)
1996	3790	Water tank removed from the target region.
1997	7181	Preliminary results at Neutrino 1998
1998	$\simeq 3000$	End of data taking 21 dec 1998

ν_e detected and flux measured by $\nu_e \, ^{12}C \rightarrow ^{12} N_{gs} e^-$ and $\nu_e \, e^- \rightarrow \nu_e \, e^-$



$\overline{\nu}_\mu$ flux known at 7% through the results of a subsidiary experiment.

ν_μ detected and flux measured by $\nu_\mu^{12}C \rightarrow ^{12} N_{gs} \mu^-$



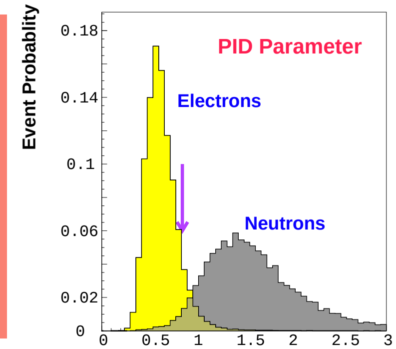
DAR OSCILLATION SEARCH

prompt positron signal, energy range.

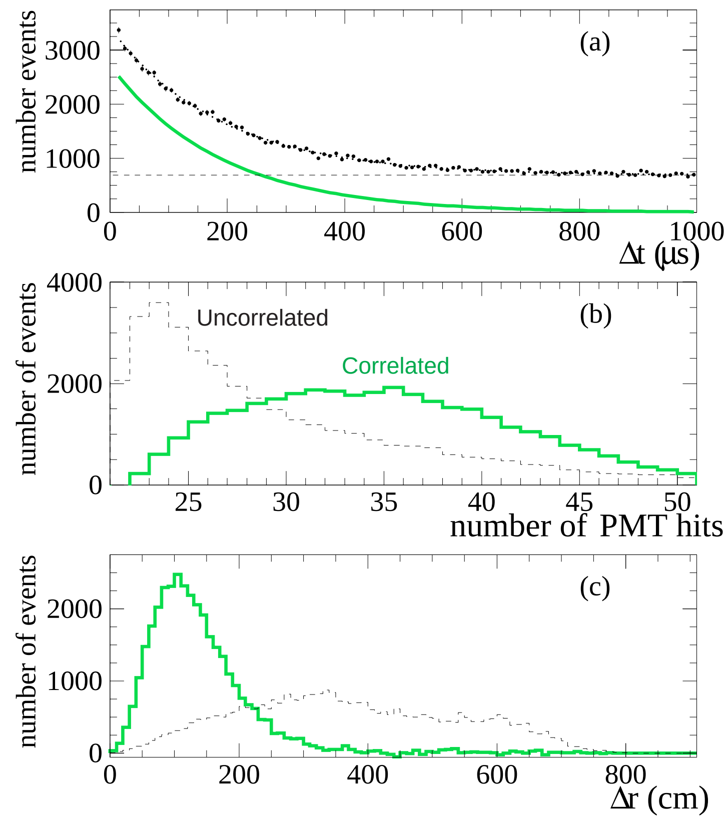
$$\overline{\nu_e}\, p \rightarrow e^+ n$$

$$n + p \underset{\tau \simeq 186\ \mu s}{\longrightarrow} d + \gamma(2.2\, MeV)$$

delayed correlated photon.



1. Particle identification through position, direction, #PMT (e^- calibration through Michel e^- from CR μ decays)
2. CR veto through veto on detector activity before and after the trigger.
3. Correlated γ through likelihood function $\mathcal{R}$ (built with CR muons and/or MC)
4. Energy range: $20 \leq E_e \leq 60$ or $36 \leq E_e \leq 60\ MeV$ (golden sample).



Overall $\overline{\nu}_e$ detection efficiency: 22%

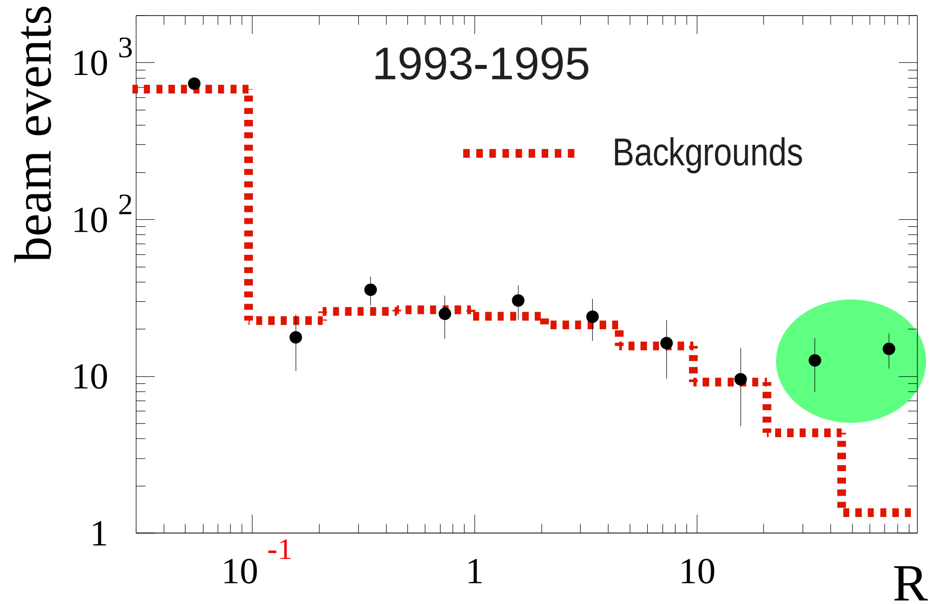
BACKGROUNDS

1. Cosmic Rays. Measured in beam off data (beam-off/beam-on$\simeq 13$, $\rightarrow$ good statistical accuracy for background subtraction).
2. Beam interactions with a random γ (measured)
3. Genuine $\overline{\nu}_e$ and $\overline{\nu}_\mu$ with a correlated γ. Studied via MC simulations.

Expected backgrounds for the 1993-1995 period $36 < E_e < 60$ MeV

Background	Neutrino Source	Events with $R \geq 0$	Events with $R > 30$
Beam Off		160.5 ± 3.4	2.52 ± 0.42
Beam-Related Neutrons		< 0.7	< 0.1
$\bar{\nu}_e p \rightarrow e^+ n$	$\mu^- \rightarrow e^- \nu_\mu \bar{\nu}_e$ DAR	4.8 ± 1.0	1.10 ± 0.22
$\bar{\nu}\ p \rightarrow \mu^+ n$	$\pi^- \rightarrow \mu^- \bar{\nu}_\mu$ DIF	2.7 ± 1.3	0.62 ± 0.31
$\bar{\nu}_e p \rightarrow e^+ n$	$\pi \rightarrow e\nu$ and $\mu \rightarrow e\nu\bar{\nu}$ DIF	0.1 ± 0.1	0
Total with Neutrons		7.6 ± 1.8	1.72 ± 0.41
$\nu_\mu \mathrm{C} \rightarrow \mu^- X$	$\pi^+ \rightarrow \mu^+ \nu_\mu$ DIF	8.1 ± 4.0	0.05 ± 0.02
$\nu_e\ {}^{12}C \rightarrow e^-\ {}^{12}N$	$\mu^+ \rightarrow e^+ \bar{\nu}_\mu \nu_e$ DAR	20.1 ± 4.0	0.12 ± 0.02
$\nu_e\ {}^{13}C \rightarrow e^-\ {}^{13}N$	$\mu^+ \rightarrow e^+ \bar{\nu}_\mu \nu_e$ DAR	22.5 ± 4.5	0.14 ± 0.03
$\nu e \rightarrow \nu e$	$\mu^+ \rightarrow e^+ \bar{\nu}_\mu \nu_e$ DAR	12.0 ± 1.2	0.07 ± 0.01
$\nu e \rightarrow \nu e$	$\pi \rightarrow \mu \nu_\mu$ DIF	1.5 ± 0.3	0.01 ± 0.01
$\nu_e \mathrm{C} \rightarrow e^- X$	$\pi \rightarrow e \nu_e$ DAR	3.6 ± 0.7	0.02 ± 0.01
$\nu_\mu \mathrm{C} \rightarrow \pi X$	$\pi \rightarrow \mu \nu_\mu$ DIF	0.2 ± 0.1	0
$\nu_e \mathrm{C} \rightarrow e^- X$	$\pi \rightarrow e\nu$ and $\mu \rightarrow e\nu\bar{\nu}$ DIF	0.6 ± 0.1	0
Total without Neutrons		68.6 ± 9.5	0.41 ± 0.06
Grand Total		236.7 ± 10.2	4.65 ± 0.59
100% Transmutation	$\mu^+ \rightarrow e^+ \bar{\nu}_\mu \nu_e$ DAR	12500 ± 1250	2875 ± 345

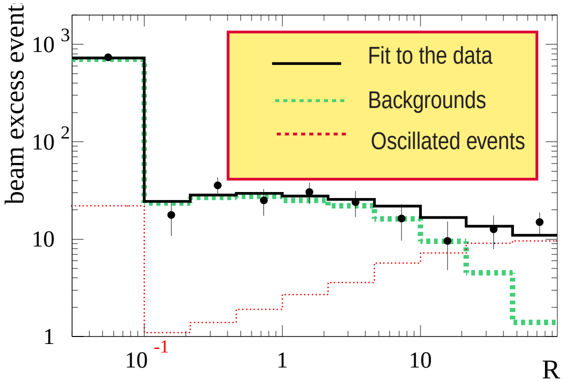
EXCESS OF $\overline{\nu_e}$ EVENTS

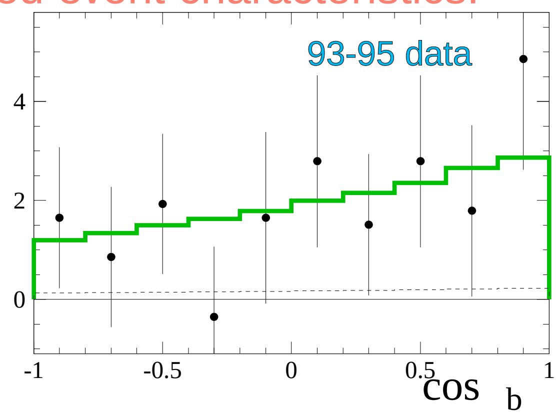


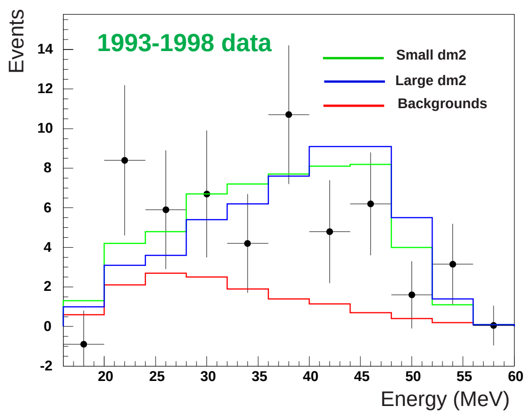
Events with $20 \leq E_e \leq 60\ MeV$, $R > 30$:

Year	Coulomb	Beam ON	Beam Off	ν bgd	Excess	Oscill. Prob.(%)
93-95	14772	38	9.2 ± 0.8	7.7 ± 0.8	21.1 ± 6.3	$0.31 \pm 0.12 \pm 0.05$
96-98	13971	32	8.5 ± 0.6	5.1 ± 0.6	18.4 ± 6.1	$0.32 \pm 0.15 \pm 0.05$
Total	28743	70	17.7 ± 1.0	12.8 ± 1.7	39.5 ± 8.8	$0.31 \pm 0.09 \pm 0.05$

Excess events fit oscillated event characteristics:

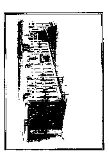






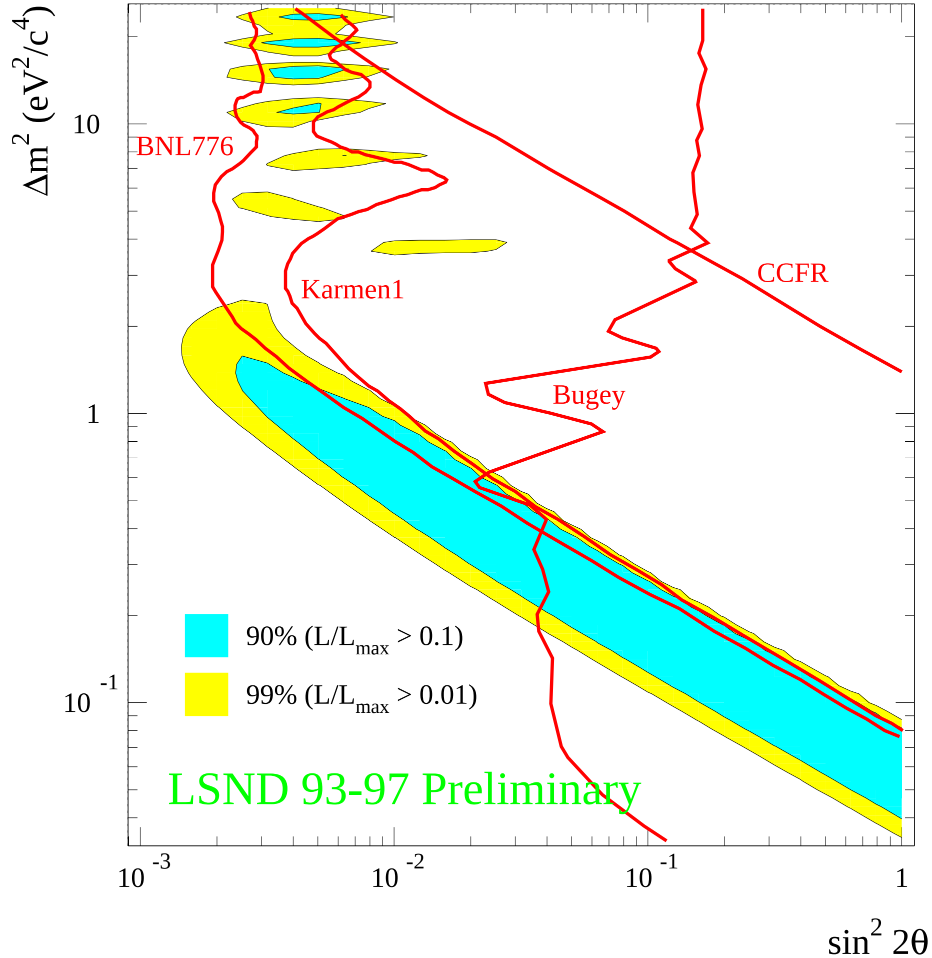
While don't fit backgrounds:

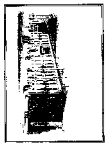
- Fit the excess with the μ^- background: it must be multiplied by 8.6 and χ^2 is 2.2 units worse than oscillation fit
- π^- DIF backgrounds studied with a special trigger during 1995, in order to increase sensitivity to muons associated to small activity: it resulted compatible with the MC predictions.



SIGNAL PLOT

- Built with all the events with $20 \leq E_e \leq 60\ MeV$ (1763 events in 1993-95), using the energy, the likelihood R, the angle respect the beam direction ($\cos\theta_b$) and the path length L
- Systematics included: neutrino flux $\times$ detection efficiency $= 10\%$.
- Bidimensional ($sin^2(2\theta), \Delta m^2$) grid, selecting $\Delta\chi^2 = 2.6(90\%)$ and $4.5(99\%)$ above the minimum.
- The other exclusion curves in the plot are built with several different statistical methods!.





$\nu_\mu \to \nu_e$ DIF analysis

- Inclusive reaction $\nu_e C \to e^- X$
- No correlated γ: single signature.
- No ν_e from μ DIF $\to$ selection based on electron energy: $60 < E_e < 200$ MeV.
- Longer tracks $\to$ Č/scintillation light more favorab
  $\to$ better particle identification.

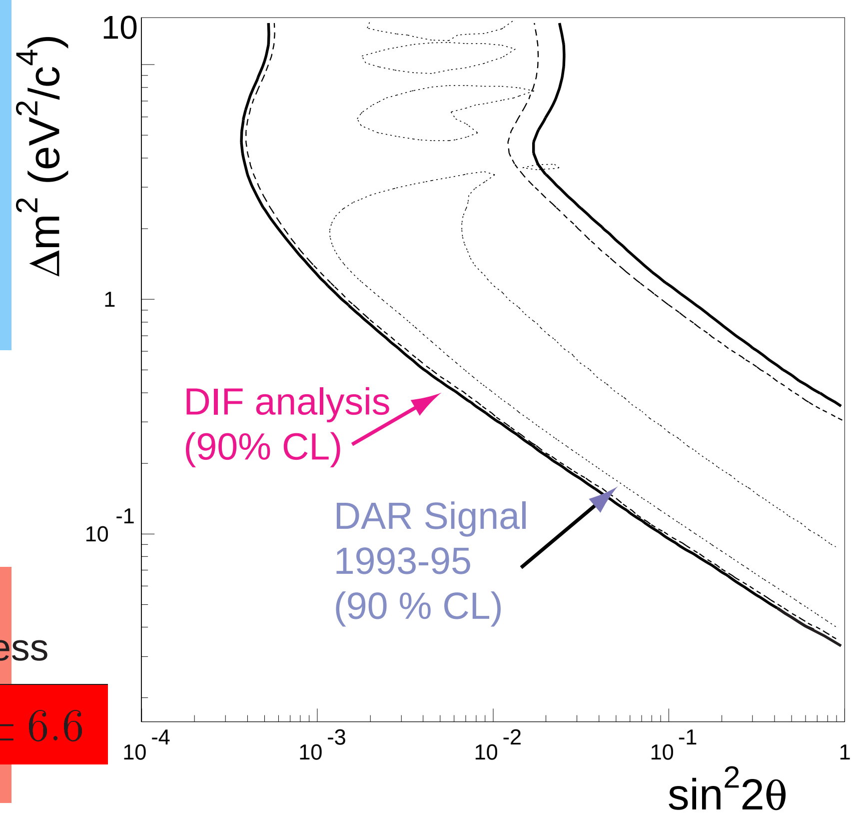
- Different systematics AND different backgrounds
- Additional problems. i.e. Measured inclusive $\nu_\mu C$ cross section disagrees with the prediction by -45% in this energy range (included in the systematics).

$\Downarrow$

Similar Result

Year	Beam ON	Beam Off	ν bgd	Excess
93-95	40	10.5 ± 0.8	9.6 ± 1.9	18.6 ± 6.6

Oscillation Probability: $2.6 \pm 1.3 \pm 0.5 \cdot 10^{-3}$.



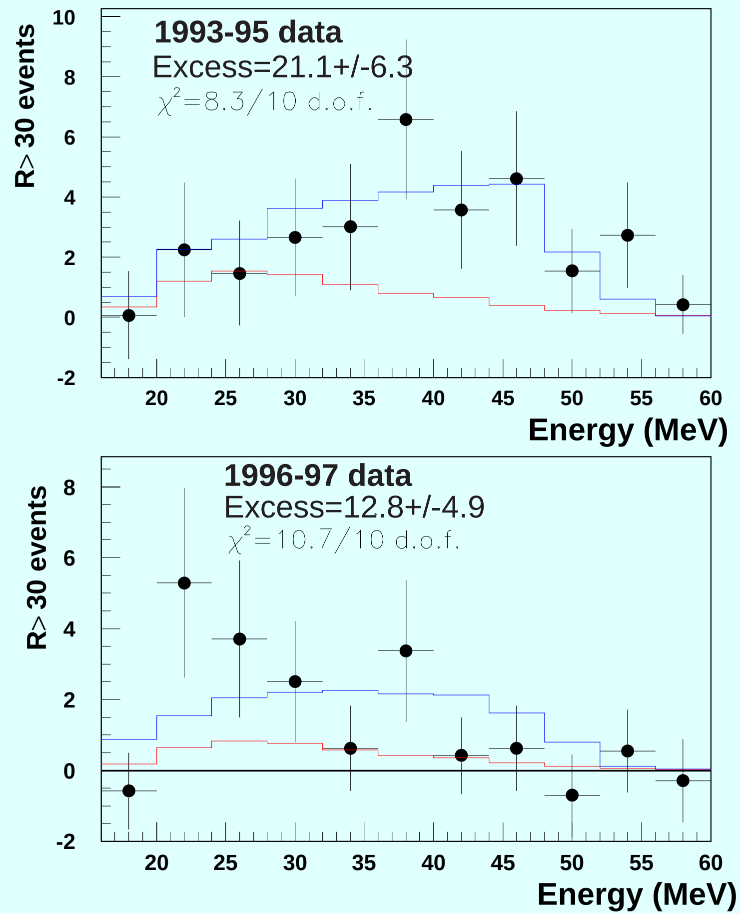
About the presumed discrepancy between 1993-1995 and 1996-1998 data

In 1996-1998 the data was collected without the 30 cm long water target upstream of the beam dump. The neutrino flux in 1996-1998 compared to 1993-1995 was only 2/3 for DAR and 1/2 for DIF.

The reason for the change in beam-stop configuration is that the accelerator funding changed from nuclear physics to testing tritium production.

Excess events ($R > 30$) in different periods.

Years	Energy (MeV)	Excess	Expected (low Δm^2)	σ
93-95	20-36	3.7 ± 4.2	11.0	1.7
93-95	36-60	17.4 ± 4.7	14.1	0.7
96-98	20-36	12.3 ± 5.1	6.7	1.1
96-98	36-60	6.1 ± 3.4	7.7	0.5
93-98	20-36	16.0 ± 6.6	17.7	0.3
93-98	36-60	23.5 ± 5.8	21.8	0.3



KARMEN EXPERIMENT

Performed at ISIS neutron spallation facility at RAL.

The detector (56 t), is at 17 m, 90^0, from the beam stop. Beam current is 0.2 mA.

The time structure of the beam permits a separation between neutrinos from μ^+ DAR and those from π decay (both DAR and DIF).

KARMEN 1: 1990-1995, 9120 Coulombs. Seen 171 events, expected 140 from cosmic rays and beam backgrounds.
Beam excess $= 31 \pm 17$ (2.4σ), delayed event seen but prompt positron do not exhibit time and energy distribution from oscillations. A lower limit on oscillation probability: $P(\overline{\nu}_\mu \rightarrow \overline{\nu}_e) < 4.25 \cdot 10^{-3}$ $(90\% CL)$ was set.
Also performed a search for $\nu_\mu \rightarrow \nu_e$ oscillation, with a 90% CL limit of $2 \cdot 10^{-2}$ on the probability.

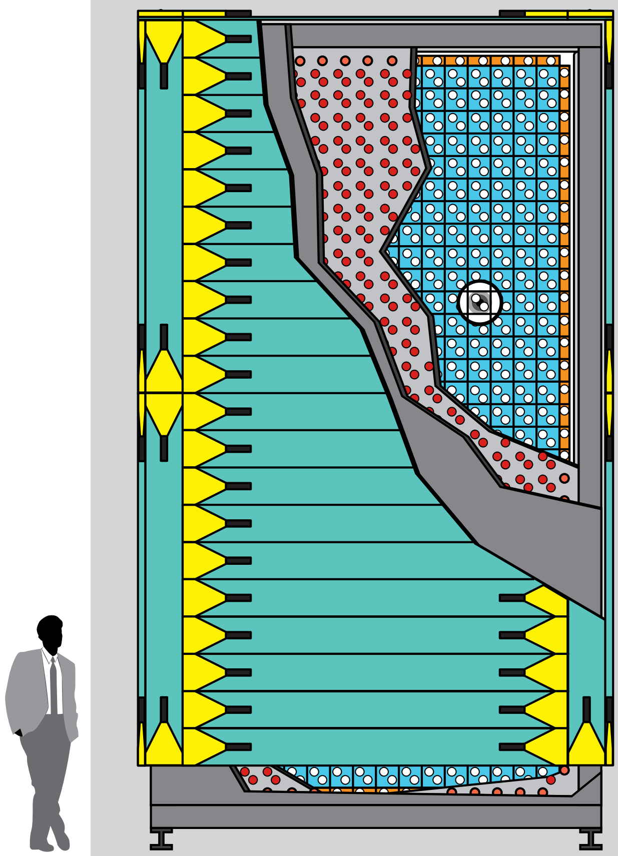
UPGRADE (KARMEN 2): new 300 m^2 active veto layer surrounding the iron blockhouse (4λ)

- throughgoing or stopping muons can be off-line vetoed
- Cosmic background suppression reduced by a factor 43.

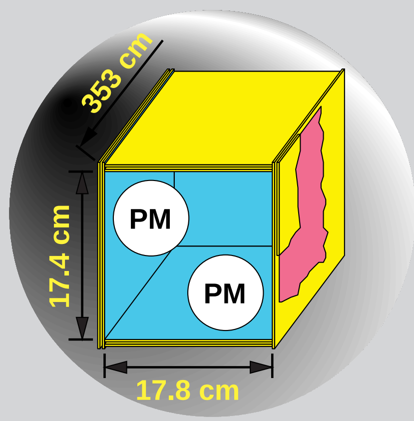
KARMEN DETECTOR

56t liquid scintillator calorimeter

96% active volume



OUTER VETO 1	**NE110**
PASSIVE SHIELD	**20 cm**
INNER VETO	**96**
SEGMENTED CENTRAL DETECTOR	**16x32**
3" PHOTOMULTIPLIER	
ACRYLIC GLASS	



Gd_2O_3 PAPER + AIR GAP

3.2m x 5.9m x 3.5m

$$\Delta E/E = \frac{11.5\%}{\sqrt{E(\mathrm{MeV})}} \quad (<=> 80\ \mathrm{pe/MeV})$$

$\sigma t = 0.4$ns

$\sigma x = 6.0$cm

17.05.98

Karmen data analysis

Window Analysis (similar to Karmen 1): event selection through simple cuts and no likelihoods:

Prompt Event	Visible Energy: 20-50 MeV. time: 0.6-8.6 μs after beam no activity in any of 3 veto sys.	**Sequential Event**	Visible energy: 0-5.5 MeV time difference: 5-270 μs positron correlation: $\Delta x < 60\ cr$

Δt **cuts** on previous detector activity.

The cuts are optimized for low Δm^2 $(0.1 - 1\ eV^2)$.

Likelihood Analysis (a la LSND): relax the cuts and build likelihood functions for prompt and delayed eve selection (VERY PRELIMINARY).

BACKGROUNDS

(normalized to Feb 97-Nov 98, window analysis)

Cosmics (meas.)	0.90 ± 0.08
sequential $\nu_e C^{12}$ (meas.)	1.28 ± 0.20
random $\nu_e C^{12}$ (meas.)	0.95 ± 0.10
intrinsic $\overline{\nu}_e$ contamination (MC)	0.65 ± 0.07
Total	3.79 ± 0.30

Karmen2 Data Progression

DATA TAKING	Coulombs	Expected Backgrounds	Events	N^* (full mixing)	$sin^2(2\theta)$ $(\Delta m^2 \to \infty)$	Sensitivity*
Feb.97-Apr.98	2897	2.88	0	811	$1.3 \cdot 10^{-3}$	$5.4 \cdot 10^{-3}$
Feb.97-Jun.98	3268	3.25	1	950	$1.8 \cdot 10^{-3}$	$4.5 \cdot 10^{-3}$
Feb.97-Nov.98	3731	3.79 ± 0.30	3	1058 ± 107	$3.5 \cdot 10^{-3}$	$4.2 \cdot 10^{-3}$
Feb.97-Nov.98 (likelihood)	3731	9.30 ± 0.74	7	1384 ± 152	$1.9 \cdot 10^{-3}$	$2.3 \cdot 10^{-3}$

* Sensitivity is defined as the average limit for an experiment that doesn't see any signal and detects the expected background.

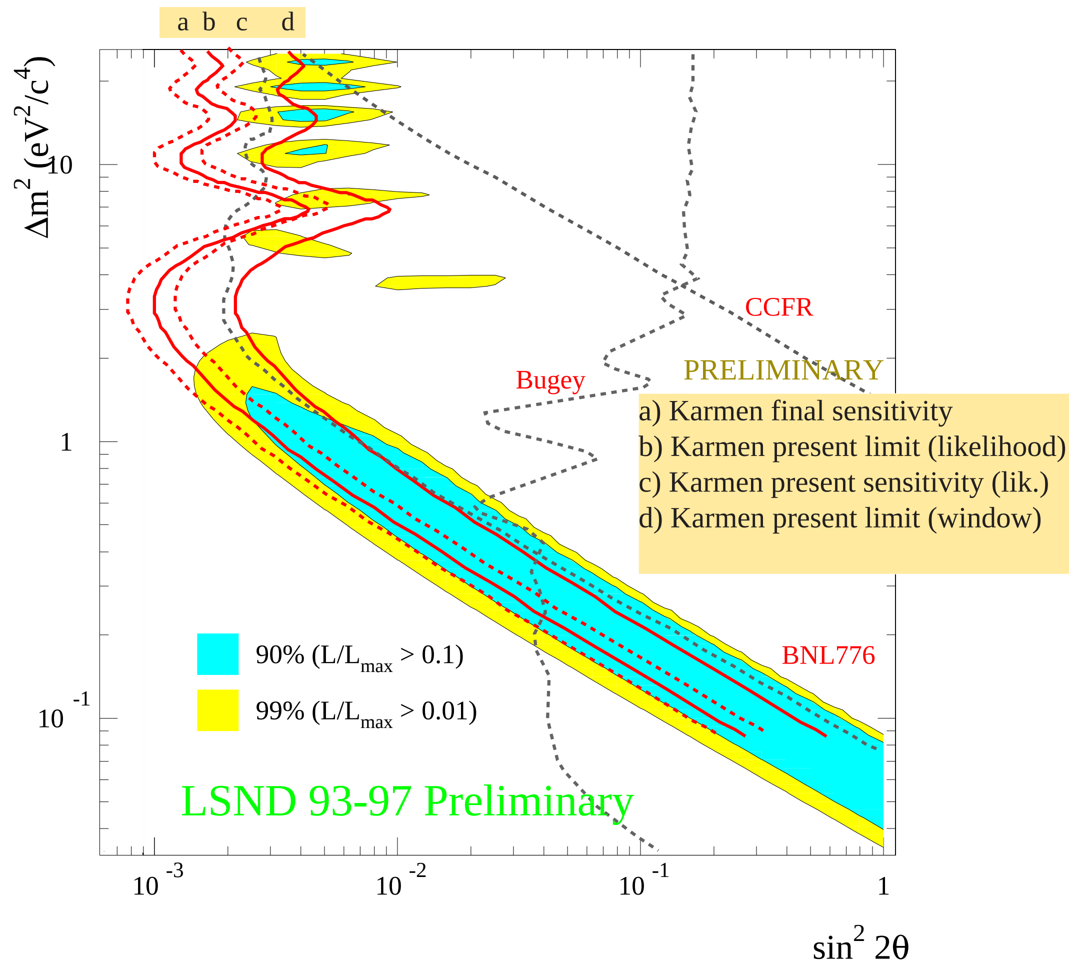
Latest results no longer show a large disagreement between background prediction and events seen: the physic result no longer depends onfrom the statistical method adopted.

The 1998 ISIS cycle finished on February, 16^{th} 1999, corresponding to 2 years of Karmen 2. Results are expect in a month or two.

The experiment will run for a further two years, reaching a sensitivity on $P(\overline{\nu}_\mu \to \overline{\nu}_e) \simeq 1.3 \cdot 10^{-3}$.

Karmen2 preliminary exclusion plots

- A purely illustrative exercise to compare 90% CL exclusion plots (Karmen) built with the Cousins-Feldman method, with the LSND preferred signal regions.
- Karmen results must be considered very preliminary and a final analysis for the Feb.97-Feb.99 period is expected next month.
- Also LSND results are preliminary and again the final, complete, data analysis is expected in a month or two.
- Karmen final sensitivity is calculated for 4 years of data taking. A negative result will be not conclusive.



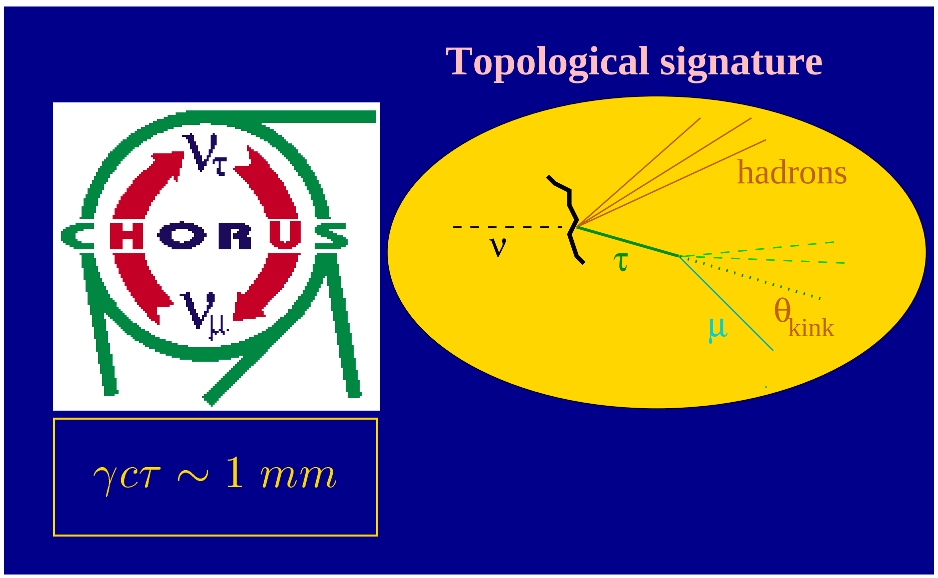
LSND vs. KARMEN

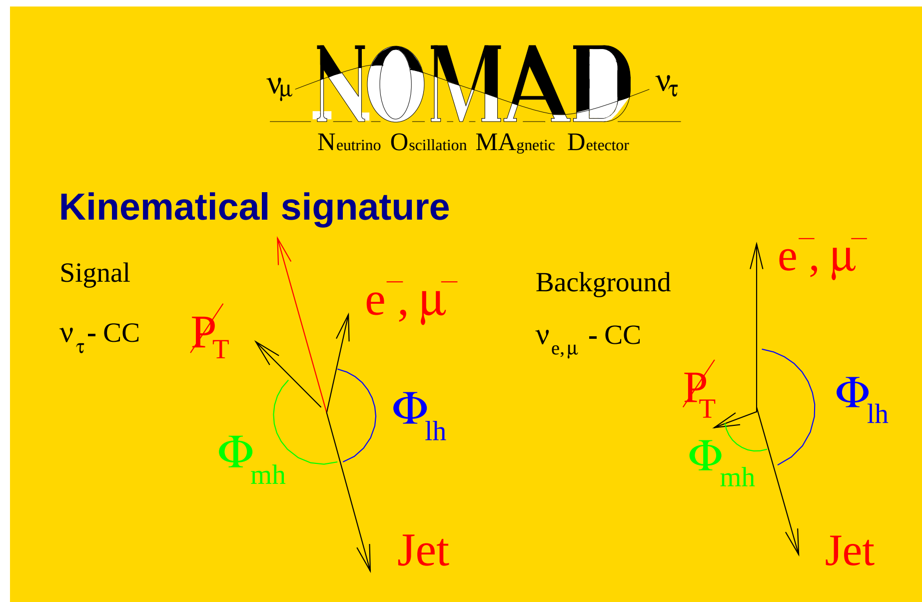
	LSND	KARMEN
Accelerator	LAMPF	ISIS
Proton Energy	800 MeV	800 MeV
Proton Current	1 mA	0.2 mA
Duty factor	$6 \cdot 10^{-2}$	$5 \cdot 10^{-4}$
Angle from proton beam axis	17^0	90^0
Distance from target	30 m	17.5 m
Timing separation μ/π	No	Yes
Detector mass	167 tons	56 tons
Detection	Scint + $\hat{C}erenkov$	Scint.
Event location	timing	segmentation
Energy resolution	$\frac{43\%}{\sqrt{E\,(MeV)}}$	$\frac{11\%}{\sqrt{E\,(MeV)}}$
Particle id.	Yes	No
Neutron capture	proton (2.2 $MeV \gamma$)	Gd (8 $MeV\ \gamma$)
Integrated charge	$\sim 28700\ C$	9211+3731
Relative Detection Event Rate ($\overline{\nu}_e\ + p \rightarrow e^+ + n$)		
High $\Delta m^2 (> 10\, eV^2)$	1.0	0.24
Small $\Delta m^2 (< 1\, eV^2)$	1.0	0.08

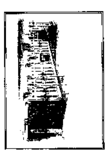
$\nu_\mu \to \nu_\tau$ search at the CERN Wide Band Beam

In the mass scale above $1\ eV$, inspired by Dark Matter scale

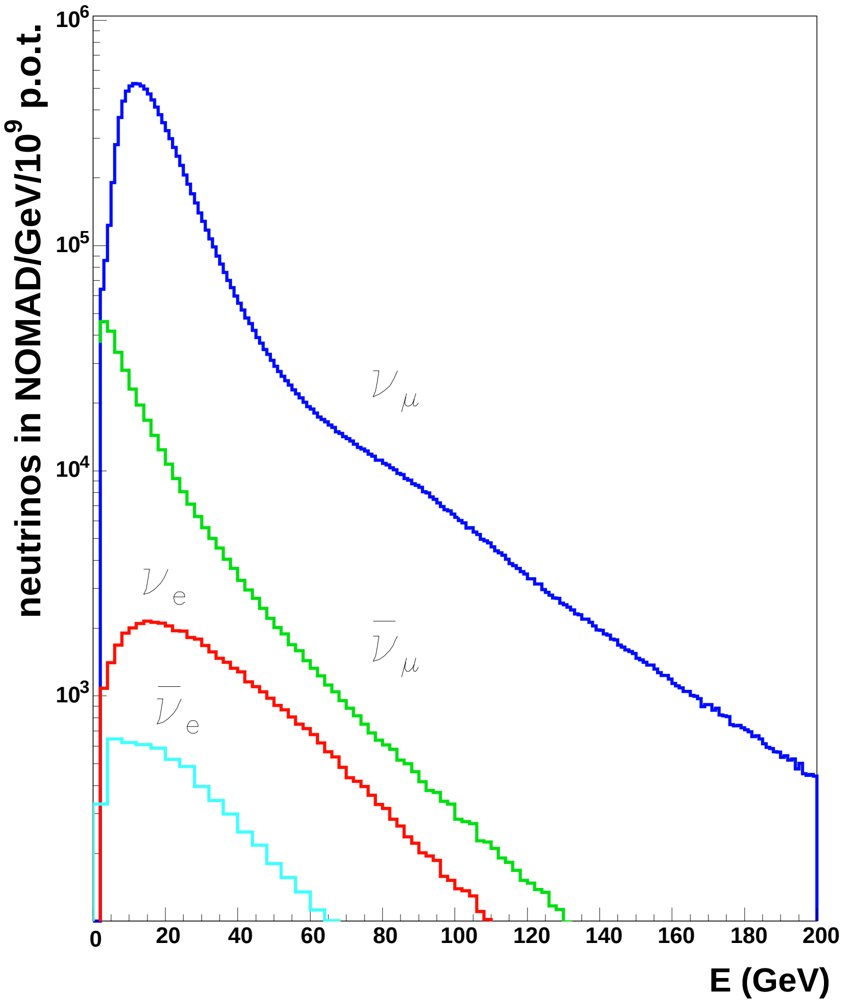
The first dedicated exploration of the $\nu_\mu \leftrightarrow \nu_\tau$ oscillation parameter space







CERN Wide Band Beam (WANF)



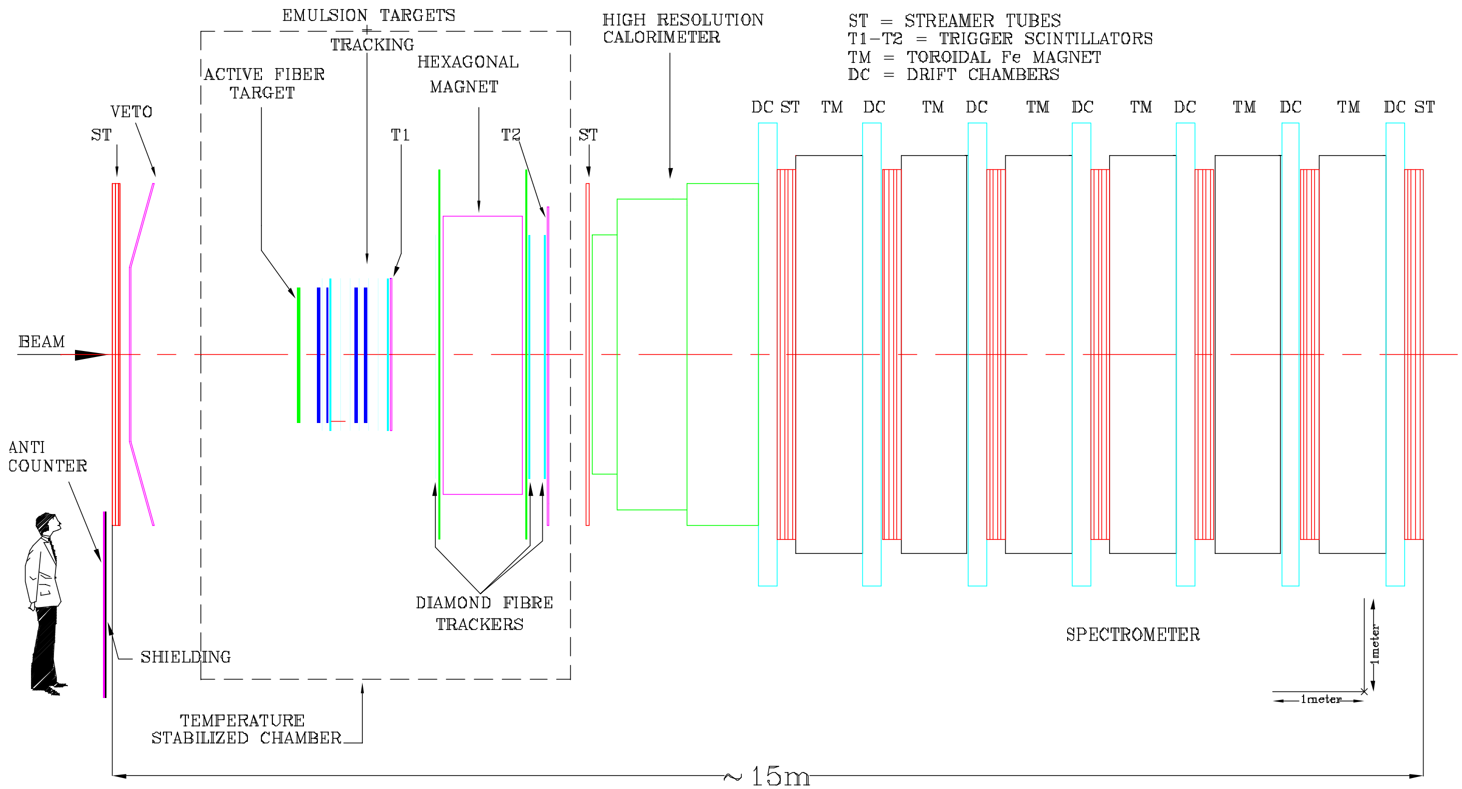
Distance of detector from target $\sim 800m$.

Effective neutrino flight path $\sim 600m$.

Flavour	Rel. Flux	$\langle E_\nu \rangle$ (GeV)
ν_μ	1	23.5
$\bar{\nu}_\mu$	0.061	19.2
ν_e	0.0094	37.1
$\bar{\nu}_e$	0.0024	31.3

ν_τ flux is negligible (less than 0.1 expected interactions in 4 years).

Chorus detector



Chorus target and target tracker

Fibre tracker: $\sim$ 10^6 scintillating fibers of $500\ \mu m$ in diameter.

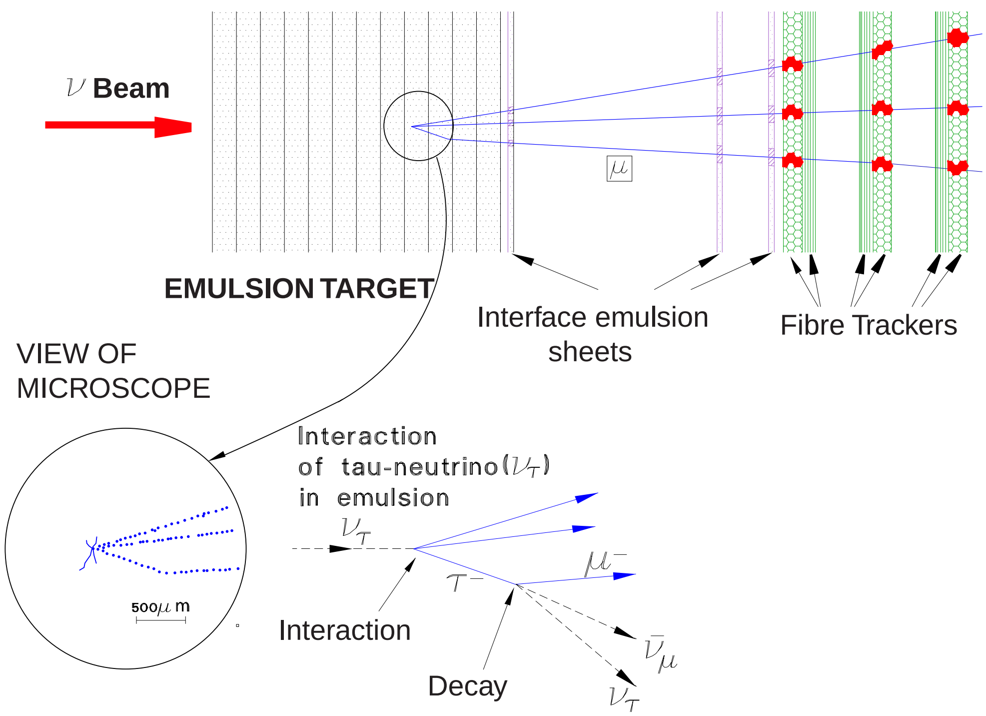
Resolutions: 2 $mrad$ and 150 μm.

Emulsion Target: $(4 \times 200\ Kg)$

Spatial resolution $\sim 1 \mu m$,

grain density $\sim 300/mm$.

Ideal to detect the τ decay kink.

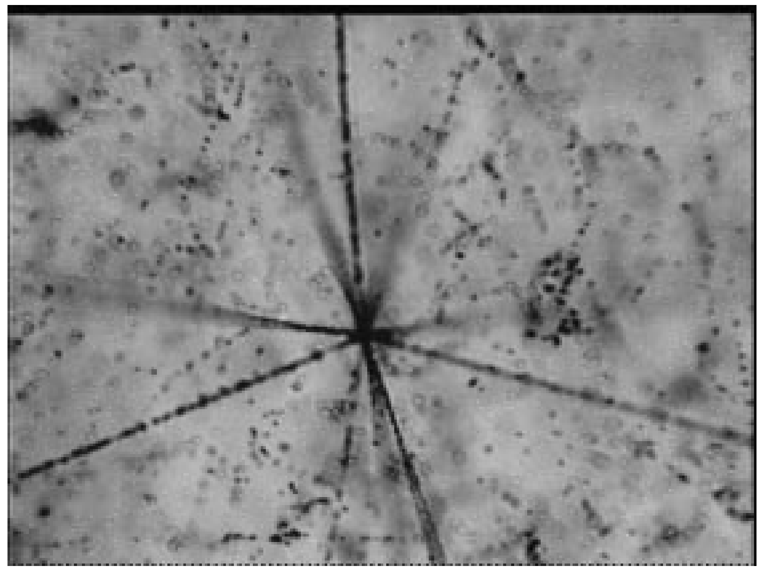


Chorus scanning

Scanning speed is dramatically increased:

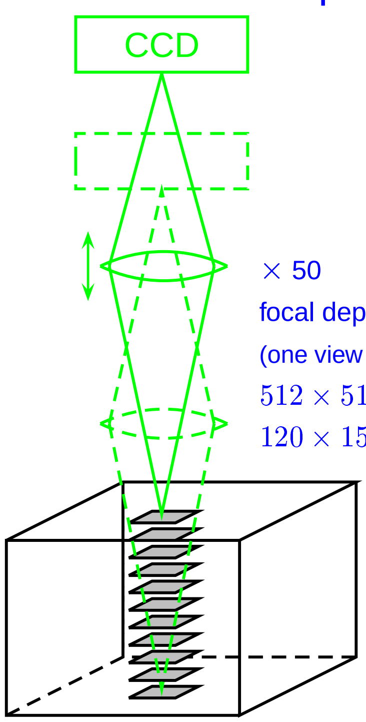
year	views/s
1994	0.5
1995	6
1998	180
2000	1800

Emulsion perpendicular to the beam



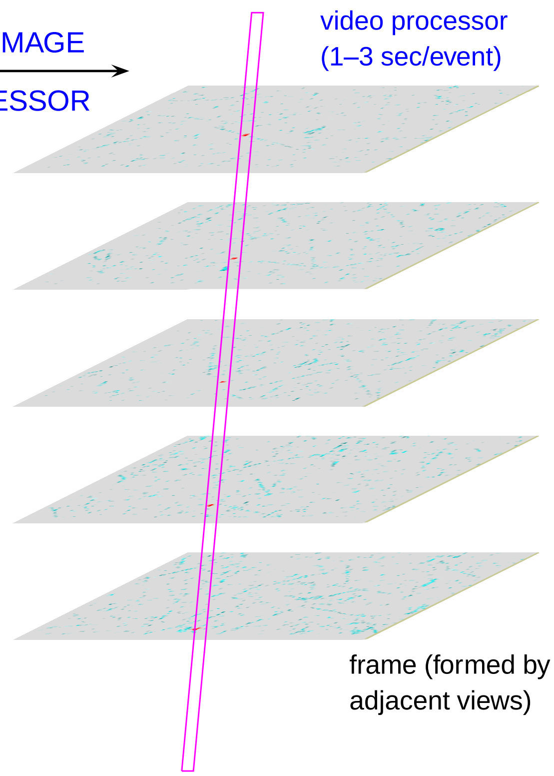
Automatic scanning: Track Selector (Nagoya)

automatic microscope



$\times$ 50
focal depth $5\mu m$
(one view
512×512 pixels
$120 \times 150 \mu m^2$)

TOMOGRAPHIC IMAGE
TO VIDEO PROCESSOR



Chorus signal definition

One Muon Channel (the golden one)

Negative μ track, $p < 30\ GeV$

No other primary lepton

Kink on muon track $p_T > 250\ MeV$

Short flight length < 5 plates (4mm)

Background

Charm production by antineutrinos (very small)

To check scanning efficiency: Use events with 2 muons in the final state ($\sim\ 2\%$ of the total) scan the emulsion searching for a kink $\rightarrow$ charm dimuon candidates (D^+ decay).

	1995	1996
Expected events	7.4 ± 0.7	15.4 ± 2.2
Events found	8	17

Zero μ channel (Sensitive to $\tau \rightarrow \nu_\tau\, h^-(nh^0)$, $\tau \rightarrow \nu_\tau\, \overline{\nu}_e\, e^-$, $\tau \rightarrow \nu_\tau\, \overline{\nu}_\mu\, \mu^-$ where the μ^- is not identified)

Negative non-muon track

$1 < p < 20\ GeV$

No primary lepton

Kink on negative track

Strict flight length cut < 3 planes

Background

Charm production by antineutrinos (very small)

NC events with a kink-like pion (0.5 events with the present statistic)

Final result

	1994	1995	1996	1997	Total
Pot/10^{19}	0.81	1.20	1.38	1.67	5.06
CHORUS efficiency	0.77	0.88	0.94	0.94	0.90
Emulsion triggers/10^3	422	547	617	719	2305
Expected CC(ν_μ)/10^3	120	200	230	290	840
1μ to be scanned	66,911	110,916	129,669	151,105	458,601
1μ scanned so far	69%	47%	59%	48%	54%
1μ vertex located	193581	215809	30,681	30,790	102,861
0μ to be scanned	17 731	279841	32,548	37,929	116,049
0μ scanned so far	60%	48%	53%	33%	47%
0μ vertex located	35491	45023	5,339	3,837	16,690

1996 and 1997 0μ not yet included in the analysis.

	1μ	$0\mu(h)$	$0\mu(e^-)$	$0\mu(\not\mu)$
$A(\tau)/A(\nu_\mu^{CC})$	1.07	0.47	0.26	0.073
B.R.	0.174	0.495	0.178	0.174
ϵ	0.35-0.52	0.26	0.13	0.25
$N^*_{\nu_\tau}$	4003	998	100	51

A: acceptance and reconstruction efficiency, **B.R.**: branching ratio, ϵ: kink finding efficiency, $N^*_{\nu_\tau}$: expected ν_τ interactions at full mixing

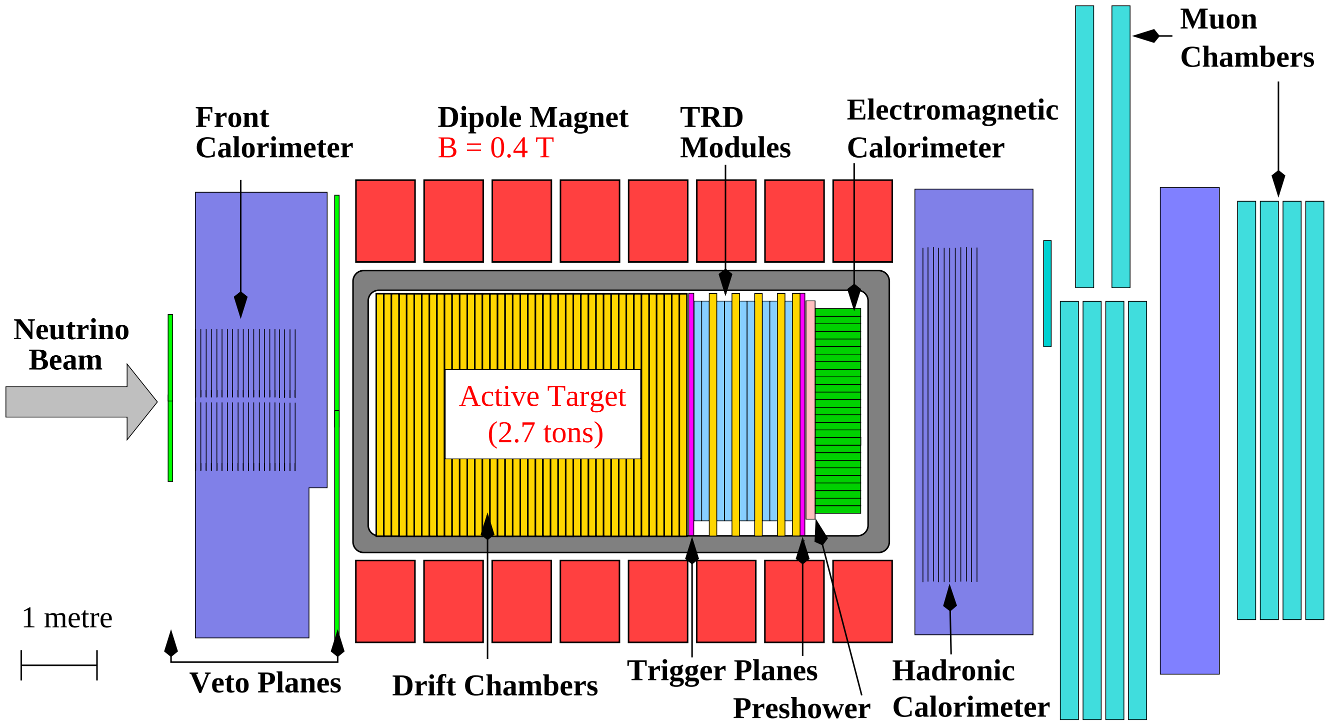
$\Downarrow$

$$P(\nu_\mu \to \nu_\tau) \leq \frac{2.38}{N^*_{\nu_\tau}} = 4.6 \cdot 10^{-4} \quad (90\% CL)$$

(2.38 takes into account 17% systematic uncertainty.)

NOMAD Detector

(NIM A404(1998)96)



- Drift Chambers (target and momentum measurement)

  Spatial resolution $< 200\ \mu$m (small angle tracks)

  Momentum resolution $\sim$ 3.5% ($p < 10$ GeV/c)

- Transition Radiation Detector (TRD) for $e^{\pm}$ identification

  π rejection $\simeq 10^3$ $\varepsilon(e) \geq 90\%$ for isolated tracks

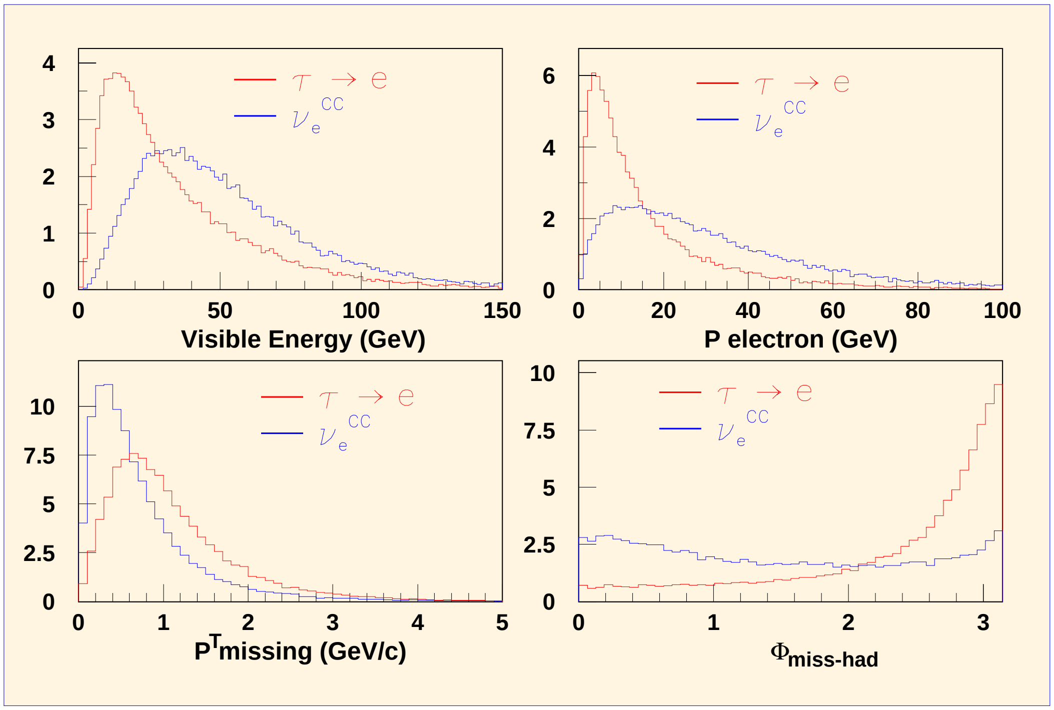
- Lead Glass Electromagnetic Calorimeter

$$\frac{\sigma(E)}{E} = 1.0\% + \frac{3.2\%}{\sqrt{E(GeV)}}$$

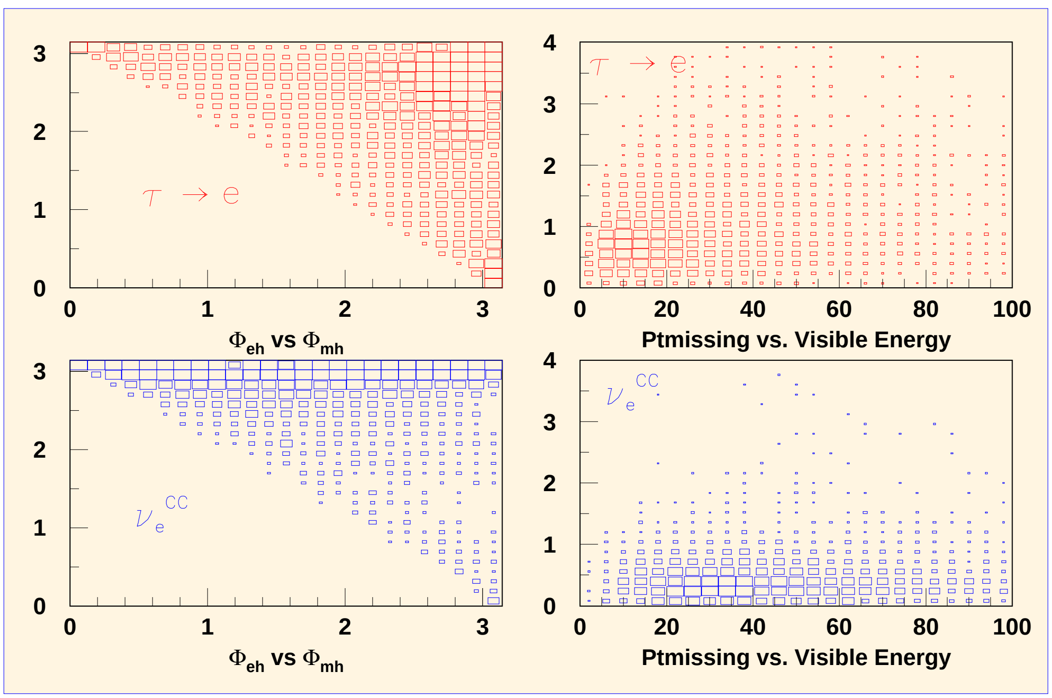
- Muon Chambers

  $\varepsilon \approx$ 97% for $p_\mu > 5$ GeV/c

Nomad hasn't a univocal signature, but has several clues of τ signals



... better if you correlate them



Extensive use of 3D likelihoods to separate signal from backgrounds

Data Simulator

- A background rejection of the order of 10^5 is required to extract the signal
- The final selection is based on “delicate" variables in the transverse plane

Monte Carlo is not enough for efficiency calculations and background predictions.
$\Rightarrow$ Data itself must be used to correct MC predictions.

Data Simulator compares a MC sample (MCS) and a Data sample (DS) of ν_μ^{CC}

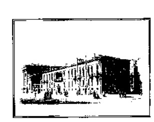
- Replace the identified μ in MC and Data by a MC lepton:
  - (a) $\mu \to \nu$ yields a “Fake NC"
  - (b) $\mu \to e$ yields a “Fake ν_e^{CC}"
  - (c) $\mu \to \tau$ yields a “Fake ν_τ^{CC}"
- Compute efficiency for signal and background as $\epsilon = \epsilon_{MC} \frac{\epsilon_{DS}}{\epsilon_{MCS}}$

Avoiding Biases & Cross-Checking Analysis

Various independent analysis’ per channel

Search for τ^+ candidates: No τ^+ signal is expected $\to$ Search for τ^+ in the data and demonstrate that background predictions agree with data.

Blind Analysis To avoid ANY bias in selecting the events, define a “signal" region and never look at the data there. Robust prediction of backgrounds must be demonstrated before analysis is authorized to “open the box". The choice of the best analysis in each decay channel is made looking for the best sensitivity, before opening the box



As an example: $\tau \rightarrow e^- \nu_\tau \overline{\nu}_e$ deep inelastic (DIS) search.

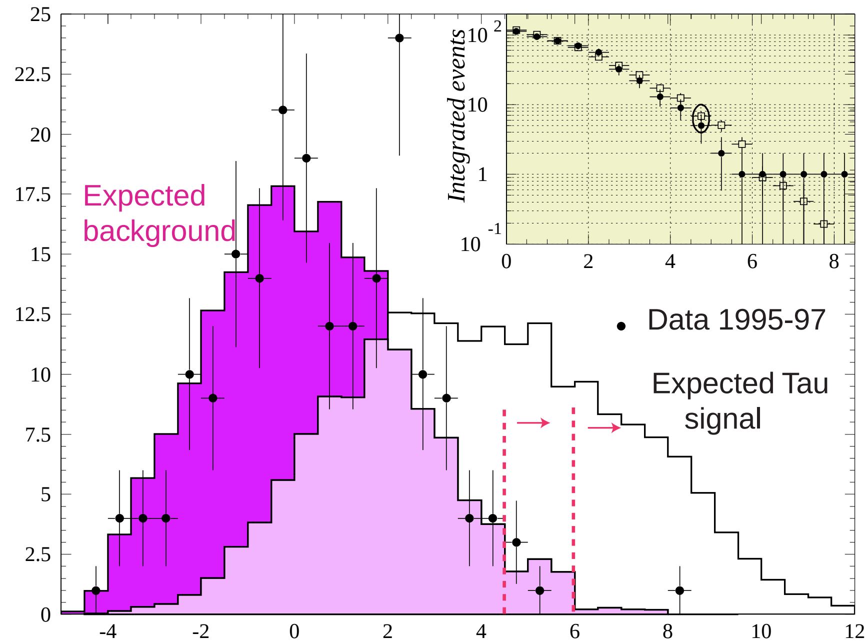
- Only one primary electron
- Tight electron identification based on TRD, preshower, ECAL.
- invariant mass cut on combination with any positive track to avoid conversions

  π^- rejection: $\mathcal{O}(10^6)$

  π^0 rejection: $\mathcal{O}(10^5)$

  electron id. efficiency: 19%
- Likelihood against NC
- Likelihood against ν_e^{CC}
- Signal box defined in the bidimensional space defined by the two likelihoods and subdivided in 5 subboxes.

Likelihood values for ν_e^{CC} rejection, after all the other cuts. Background expectation, after the data simulator correction, and data agree remarkably well.



To make optimal use of kinematical rejection, signal regions are further divided in sub-boxes

$\tau \to e$ DIS, 1995-1997

Box	Background	Data	$N_\tau^{\max}$
I	1.19 ± 0.39	0	212
II	0.42 ± 0.27	1	258
III	3.01 ± 0.67	4	620
IV	1.45 ± 0.50	0	535
V	0.28 ± 0.24	0	1193

$\tau \to hadrons$ DIS, 1995-1997

Decay Channel	Box	Background	Data	$N_\tau^{\max}$
$\tau \to h(n\pi^0)$	I	2.7 ± 0.9	3	564
	II	0.5 ± 0.5	2	200
	III	1.8 ± 0.7	0	963
$\tau \to \rho$	–	$5.0^{+1.7}_{-0.9}$	5	1891
$\tau \to 3\pi(\pi^0)$	–	6.5 ± 1.1	5	1180

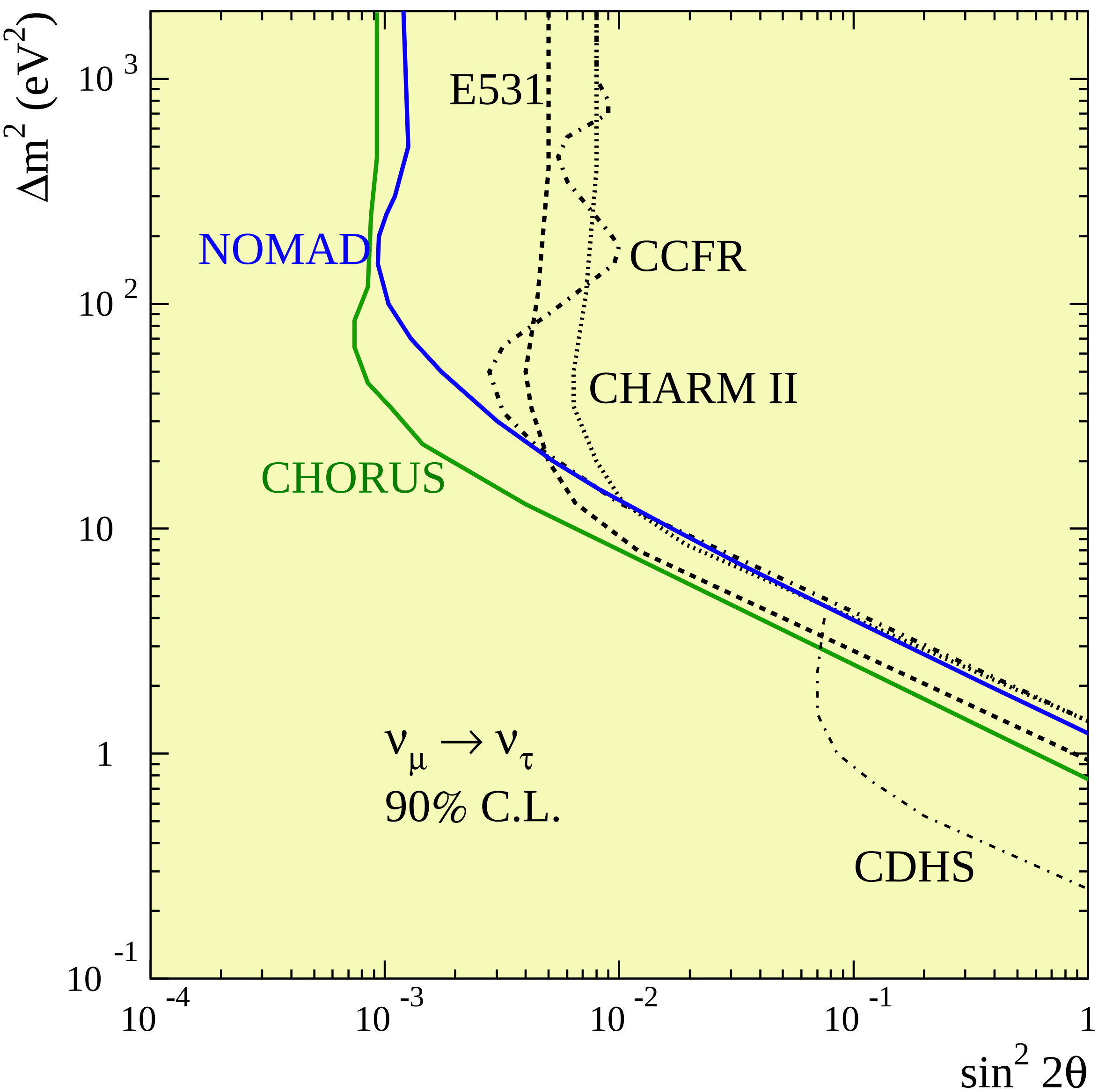
Final numbers, in 1995-97: 950000 ν_μ^{CC} in the target

Analysis	Year	τ^- Obs.	τ^- Est. Bkgnd	τ^+ Obs.	τ^+ Est. Bkgnd	$\epsilon(\%)$	$Br(\%)$	$N_\tau^{\max}$
$\tau \to e$ DIS	95-97	5	$6.3^{+1.6}_{-1.0}$	7	7.4 ± 3.1	3.5	17.8	2818
$\tau \to h(n\pi^0)$ DIS	95-97	5	5.0 ± 1.2	14	9.9 ± 2.3	0.78	49.8	1727
$\tau \to \rho$ DIS	95-97	5	$5.0^{+1.7}_{-0.9}$	13	$10.2^{+1.4}_{-1.1}$	1.6	25.3	1891
$\tau \to 3\pi(\pi^0)$ DIS	95-96	5	6.5 ± 1.1	14	13.5 ± 1.4	2.9	15.2	1180
$\tau \to e$ LM	95	0	$0.5^{+0.6}_{-0.2}$	1	1.1 ± 0.7	3.4	17.8	218
$\tau \to \pi(\pi^0)$ LM	95	1	$0.1^{+0.3}_{-0.1}$	6	8.8 ± 3.5	1.5	37.3	198
$\tau \to 3\pi(\pi^0)$ LM	95	0	$0.4^{+0.6}_{-0.4}$	14	11 ± 4	2.0	15.2	108

LM: Low multiplicity analysis, specialized in quasi elastic like events

CHORUS and NOMAD Neutrino Oscillation MAgnetic Detector exclusion plot

- Nomad systematic errors: 10% on τ efficiency, 20% on background estimation.
- Nomad plot built with the Cousins-Feldman method



Outlook

Still to be scanned:

- $\sim 50\%$ of 1μ events
- $\sim 80\%$ of 0μ events

Next step: rescan everithing with the phase II scanning:

- Optimization of reconstruction algorithms
- Increase in automatic scanning speed $\rightarrow$ better kink finding algorithms
- Better knowledge of the white kink background (through the measure of pion tracks along the emulsions) relevant in the 0μ events.

$$\Downarrow$$

If no candidate: $P(\nu_\mu \rightarrow \nu_\tau) \leq 10^{-4}$.

- $\nu_\mu \rightarrow \nu_\tau$: 30% of DIS and 85% of LM channels still to be analized: expect a gain in sensitivity of $\sim 1.5 \div 2$.
- $\nu_\mu \rightarrow \nu_e$: with 10^6 ν_μ^{CC}, 15000 ν_e^{CC} and a systematic error below 10% (still to be finalized) $\rightarrow$ sensitivity: $sin^2(2\theta) \sim 2 \cdot 10^{-3}$ $(\Delta m^2 > 10eV^2)$

- Non oscillation neutrino physics: mostly unexplored.